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# TECHNICAL MEMORANDUM

X-519

## EFFECT OF VERTICAL-TAIL MODIFICATIONS ON THE STATIC STABILITY CHARACTERISTICS AT A MACH NUMBER OF 2.2 OF A SUPERSONIC VTOL AIRPLANE MODEL HAVING A BROAD FUSELAGE AND SMALL DELTA WINGS


By Ross B. Robinson and M. Leroy Spearman

Langley Research Center
Langley Field, Va.




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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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TECHNICAL MEMORANDUM X-519

# EFFECT OF VERTICAL-TAIL MODIFICATIONS ON THE STATIC STABILITY CHARACTERISTICS AT A MACH NUMBER OF 2.2 OF A SUPERSONIC VTOL AIRPLANE MODEL HAVING A BROAD FUSELAGE AND SMALL DELTA WINGS*

By Ross B. Robinson and M. Leroy Spearman

## SUMMARY

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An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.2 to determine the effects of various tail modifications on the stability characteristics of a model representative of a supersonic VTOL airplane. The original model had a broad fuselage, small delta wings, and twin vertical tails. The tail modifications included a center-line vertical tail having the same area as the original twin tails and the addition of twin ventral fins.

The results for the configuration with the original tail indicated an initially low value of directional stability $C_{n_\beta}$ that decreased rapidly with increasing angle of attack until directional instability occurred above an angle of $4.5^{\circ}$. Changing to a single tail or adding ventral fins resulted in an increase in directional stability at low angles of attack. However, with increasing angle of attack, the contribution of the single tail to $C_{n_\beta}$ decreased more rapidly than that for the original twin tails whereas the contribution of the ventral fins remained essentially constant. As a result, the most effective means of increasing the angle-of-attack range for positive $C_{n_\beta}$ was through the addition of ventral fins to the configuration with the original vertical tail.

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*Title, Unclassified.

## INTRODUCTION

Among the types of manned aircraft currently being proposed are those that combine the features of supersonic operation with the ability to take off and land vertically (VTOL). Some of the configurations being considered make use of lifting-fans in order to achieve the VTOL characteristics. If these fans are installed in the body, the result may be a rather broad, flat fuselage that might be expected to have a pronounced effect on the aerodynamic characteristics of the vehicle. Accordingly, an investigation has been undertaken in the Langley 4- by 4-foot supersonic pressure tunnel to determine the aerodynamic characteristics of a model representative of a supersonic VTOL aircraft having a broad fuselage, small delta wings, and twin vertical tails. Results of the investigation at a Mach number of 2.01 (ref. 1) indicated that the original configuration had low directional stability. An extension of the investigation has been made at a Mach number of 2.2 for which, in addition to the original configuration, tests were made with a single vertical tail and with ventral fins. The results of this investigation, with a limited analysis, are presented herein.

## SYMBOLS

All data presented herein are referred to the body system of axes except the lift and drag data which are referred to the stability system of axes. The moment reference point is at a longitudinal station corresponding to 65.35 percent of the body length. (See fig. 1(a).)

$C_L$ lift coefficient, $\text{Lift}/qS$

$C_D$ drag coefficient, $\text{Drag}/qS$

$C_m$ pitching-moment coefficient, $\text{Pitching moment}/qS\bar{c}$

$C_n$ yawing-moment coefficient, $\text{Yawing moment}/qSb$

$C_l$ rolling-moment coefficient, $\text{Rolling moment}/qSb$

$C_Y$ side-force coefficient, $\text{Side force}/qS$

$L/D$ lift-drag ratio

$q$ free-stream dynamic pressure

| | |
|---|---|
| $S$ | wing area, 1.488 sq ft |
| $\bar{c}$ | wing mean aerodynamic chord, 1.08 ft |
| $b$ | wing span, 1.77 ft |
| $\alpha$ | angle of attack, deg |
| $\beta$ | angle of sideslip, deg |
| $C_{n_\beta}$ | directional stability parameter |
| $C_{l_\beta}$ | effective dihedral parameter |
| $C_{Y_\beta}$ | side-force parameter |

## MODEL AND APPARATUS

Details of the original model with twin vertical tails are shown in figure 1; details of the ventral fins and of the single vertical tail are shown in figure 2. Geometric characteristics are given in table I. The ventral fins were located at the same spanwise station as the twin vertical tails. The body was designed to provide for an internal flow system composed of twin horizontal-ramp inlets on the sides of the body that were ducted to six simulated jet exits side by side at the base of the body. All tests were made with 0.10-inch-wide transition strips of No. 80 carborundum grains affixed 2 inches behind the fuselage nose and at the 10-percent-chord stations of the wing and tail surfaces. All control surfaces were set at zero deflection.

The model was mounted in the tunnel on a remote-controlled rotary sting. Six-component force and moment measurements were made through the use of an internal strain-gage balance.

## TESTS, CORRECTIONS, AND ACCURACY

The tests were made in the Langley 4- by 4-foot supersonic pressure tunnel with the following test conditions:

| | |
|---|---|
| Mach number | 2.2 |
| Stagnation temperature, °F | 100 |
| Stagnation pressure, lb/sq in. | 10 |
| Reynolds number, based on $\bar{c}$ | $2.44 \times 10^6$ |

The stagnation dewpoint was maintained sufficiently low ($-25^{\circ}$ F or less) so that no condensation effects were encountered in the test section.

Tests were made for an angle-of-attack range of about $-8^{\circ}$ to $16^{\circ}$ at $\beta = 0^{\circ}$ and for an angle-of-sideslip range of about $-12^{\circ}$ to $10^{\circ}$ at $\alpha \approx 0^{\circ}$ and of about $-8^{\circ}$ to $1^{\circ}$ at $\alpha = 4.6^{\circ}$, $9.1^{\circ}$, and $13.6^{\circ}$.

The angles of attack and sideslip were corrected for deflection of the balance and sting under load. The drag data have been corrected for the effects of internal flow, base pressure, and balance chamber pressure.

The estimated accuracy of the individual measured quantities is as follows:

| | |
|---|---|
| $C_L$ | ±0.0004 |
| $C_D$ | ±0.0007 |
| $C_m$ | ±0.0004 |
| $C_n$ | ±0.0001 |
| $C_l$ | ±0.0003 |
| $C_Y$ | ±0.0007 |
| $\alpha$, deg | ±0.2 |
| $\beta$, deg | ±0.2 |

## SUMMARY OF RESULTS

Modifying the vertical tail or adding ventral fins had little effect on the longitudinal characteristics shown in figure 3 other than to increase slightly the drag and reduce the lift-drag ratio.

The aerodynamic characteristics in sideslip for various angles of attack are shown in figure 4; the sideslip derivatives are shown in figure 5. The configuration with the original twin tails indicates a low value of directional stability $C_{n_\beta}$ at $\alpha = 0^{\circ}$ that decreases rapidly with increasing angle of attack until directional instability occurs at $\alpha = 4.5^{\circ}$ (fig. 5). Changing to a single tail or adding ventral fins resulted in an increase in directional stability $C_{n_\beta}$ at low angles of attack. With increasing angle of attack, however, the contribution of the single tail to $C_{n_\beta}$ decreased more rapidly than that of the original twin tails, whereas the contribution of the ventral fins remained essentially constant throughout the angle-of-attack range. As a result, the most effective means of increasing the angle-of-attack range within which positive directional stability could be

maintained was through the addition of the ventral fins to the configuration with the original twin tails. As pointed out in reference 1, the rapid decrease in vertical-tail effectiveness with increasing angle of attack is probably caused by a disturbance created by the inlet lips. The existence of such an adverse flow field is indicated by the results for the single tail wherein the effect of increasing the span of the tail within the adverse flow field causes the tail effectiveness to decrease even more rapidly as the angle of attack is increased so that at the higher angles of attack the single tail is less effective than the original twin tails.

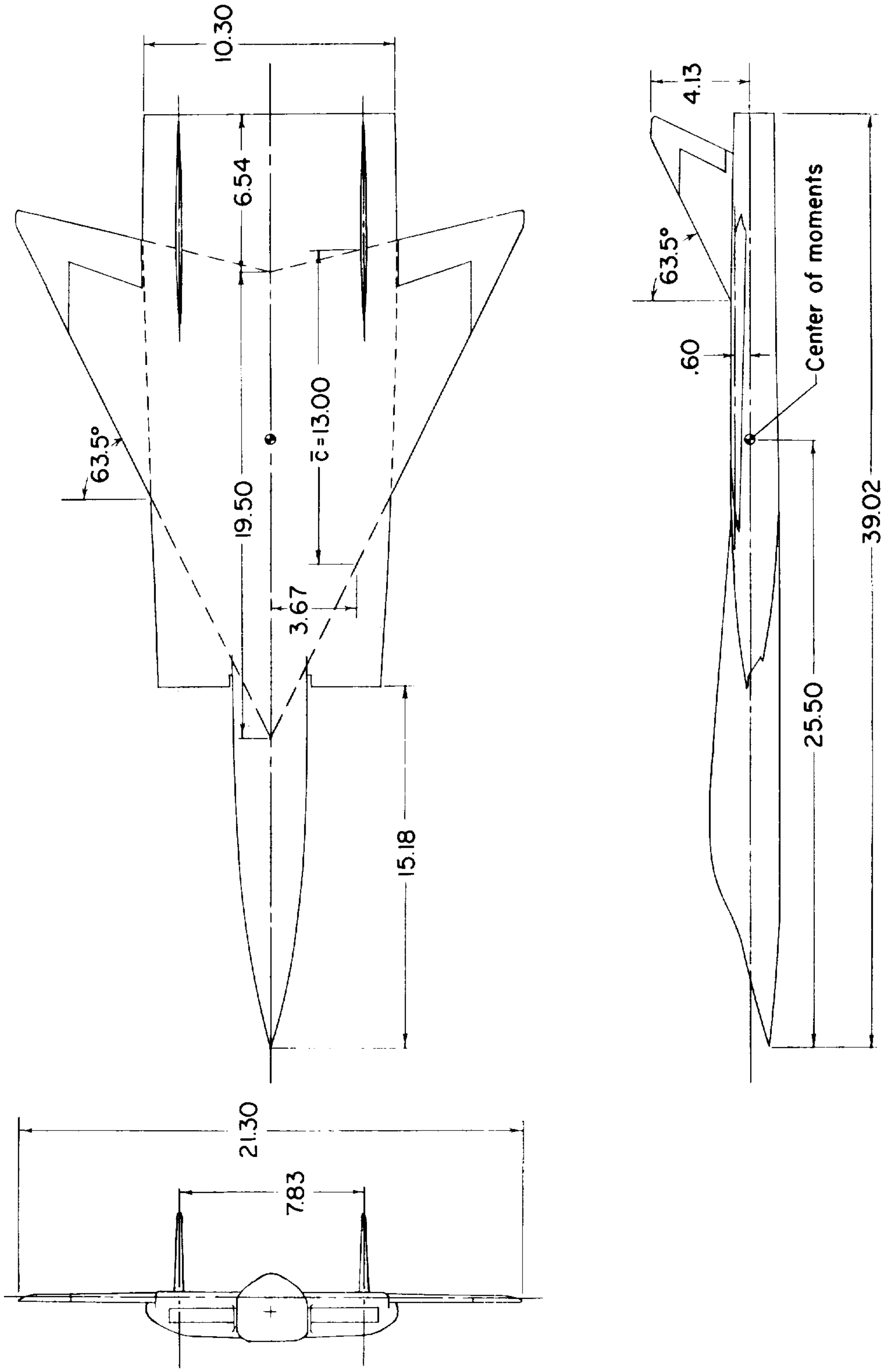
Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 26, 1961.

REFERENCE

1. Driver, Cornelius, and Spearman, M. Leroy: Stability and Control Characteristics at a Mach Number of 2.01 of a Supersonic VTOL Airplane Model Having a Broad Fuselage and Small Delta Wings. NASA TM X-441, 1961.

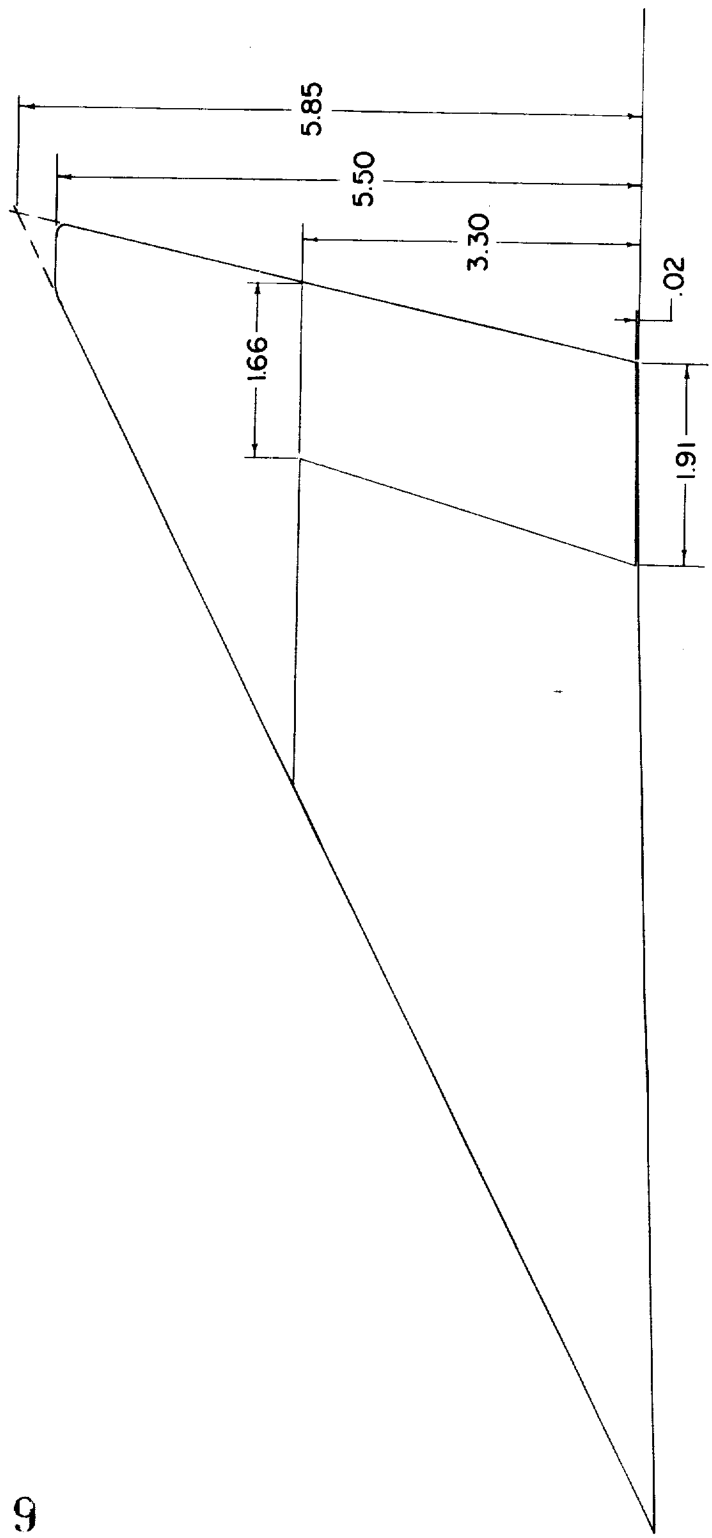
TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL

| | | |
|---|---|---|
| **Wing:** | | |
| Span, in. | | 21.30 |
| Theoretical root chord, in. | | 19.50 |
| Tip chord, in. | | 0.62 |
| Mean aerodynamic chord, in. | | 13.00 |
| Area, sq ft | | 1.488 |
| Aspect ratio | | 2.12 |
| Taper ratio | | 0.032 |
| Leading-edge sweep, deg | | 63.5 |
| Trailing-edge sweep, deg | | 13.05 |
| Sweep of quarter-chord line, deg | | 57.45 |
| Dihedral, deg | | 0 |
| Incidence, deg | | 0 |
| Thickness, percent chord | | 3 |
| Elevon area, sq ft | | 0.322 |
| **Body:** | | |
| Length, in. | | 39.02 |
| Maximum width, in. | | 10.68 |
| Body station for maximum width, in. | | 36.98 |
| Maximum depth (excluding canopy), in. | | 1.95 |
| **Vertical tails:** | Original (each) | Single |
| Span, in. | 4.13 | 5.57 |
| Root chord: | | |
| Theoretical, in. | 7.44 | 12.05 |
| Exposed, in. | 6.25 | 9.00 |
| Tip chord, in. | 1.09 | 1.60 |
| Leading-edge sweep, deg | 63.5 | 63.5 |
| Trailing-edge sweep, deg | 25.0 | |
| Area: | | |
| Theoretical, sq ft | 0.122 | 0.233 |
| Exposed, sq ft | 0.086 | 0.172 |
| **Ventral fin (each):** | | |
| Span, exposed, in. | | 1.90 |
| Root chord, in. | | 8.17 |
| Tip chord, in. | | 0 |
| Leading-edge sweep, deg | | 40 |
| Area, exposed, sq ft | | 0.067 |



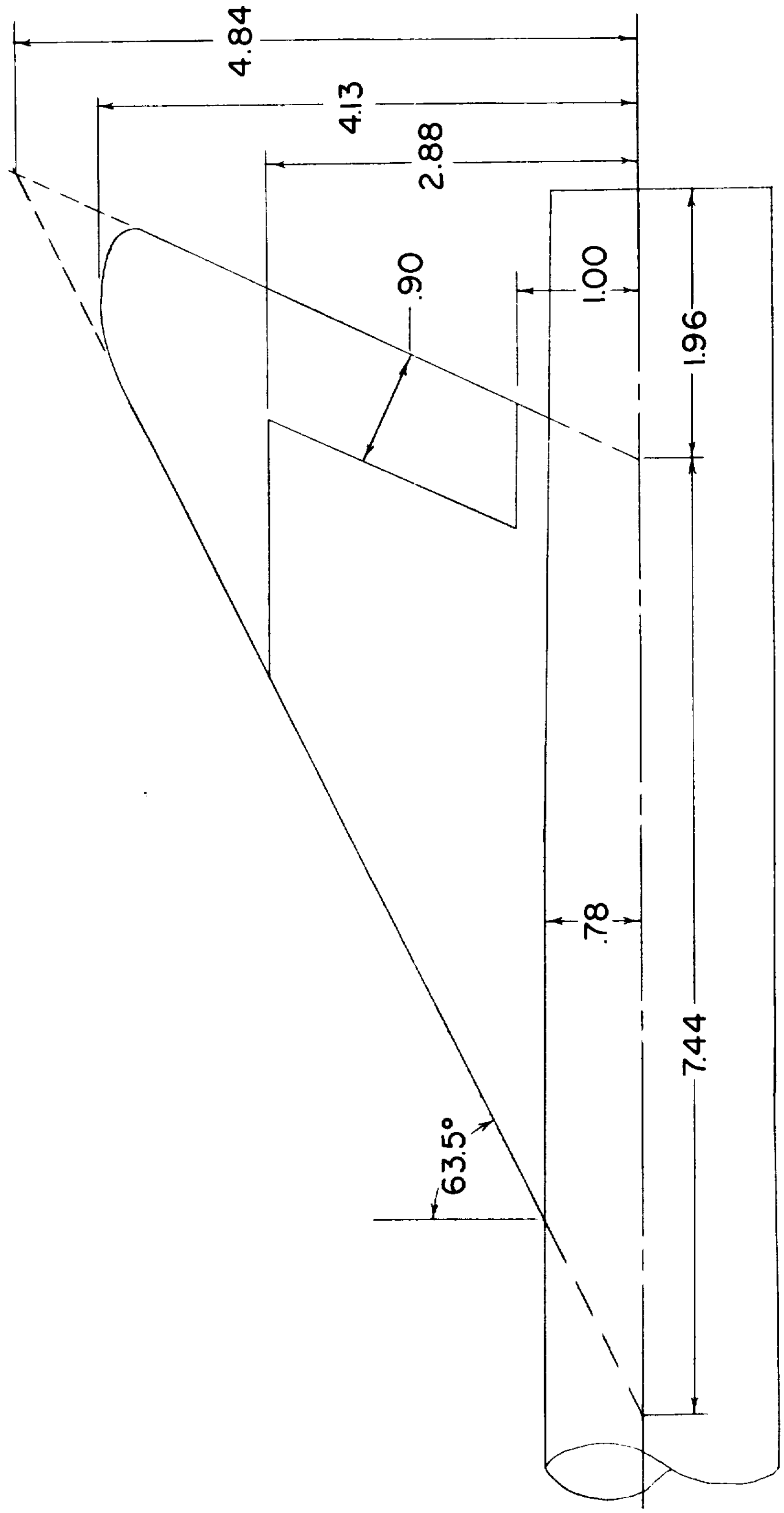

(a) Complete model.

Figure 1.- Details of model. All dimensions in inches unless otherwise noted.



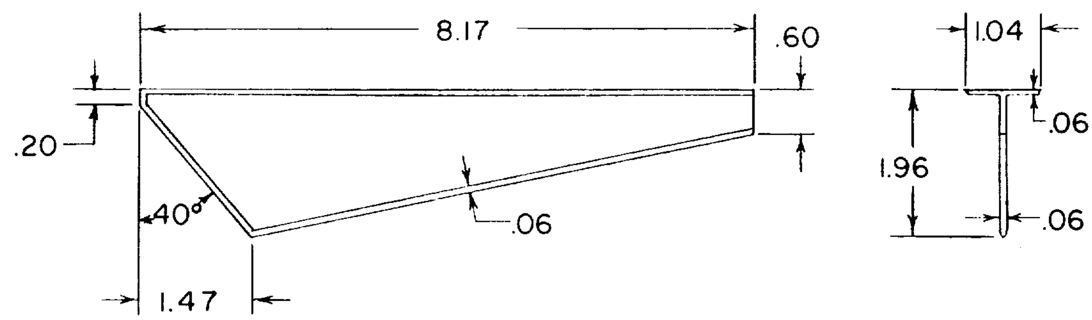

(b) Wing panel.

Figure 1.- Continued.

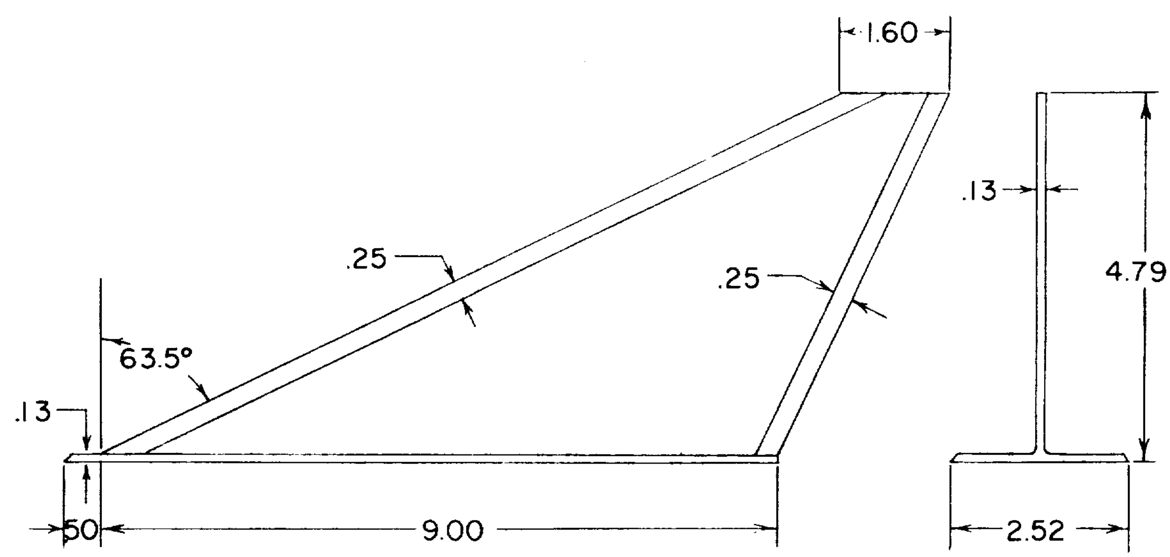



(c) Original vertical tail (each).

Figure 1.- Concluded.

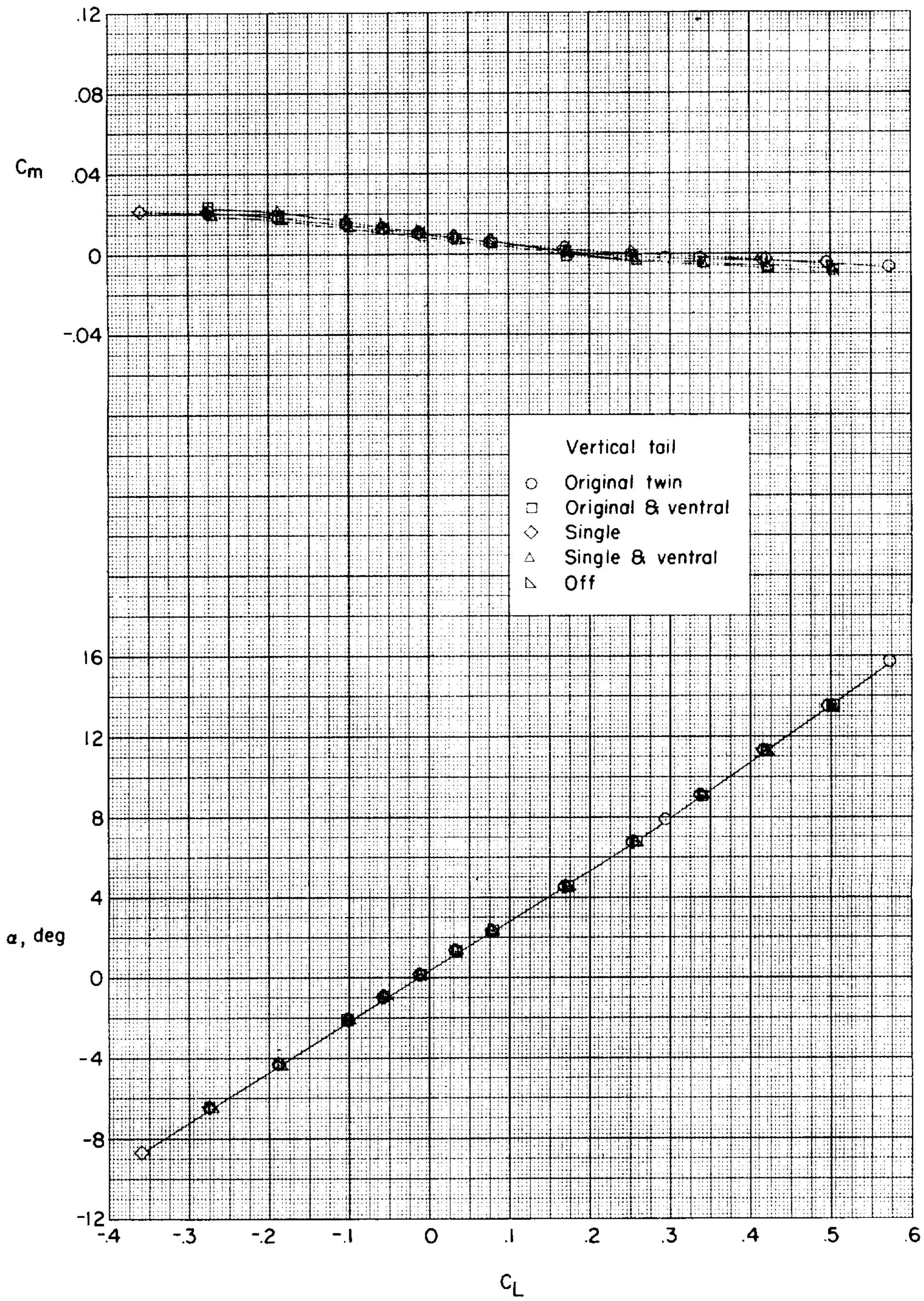



Ventral fin



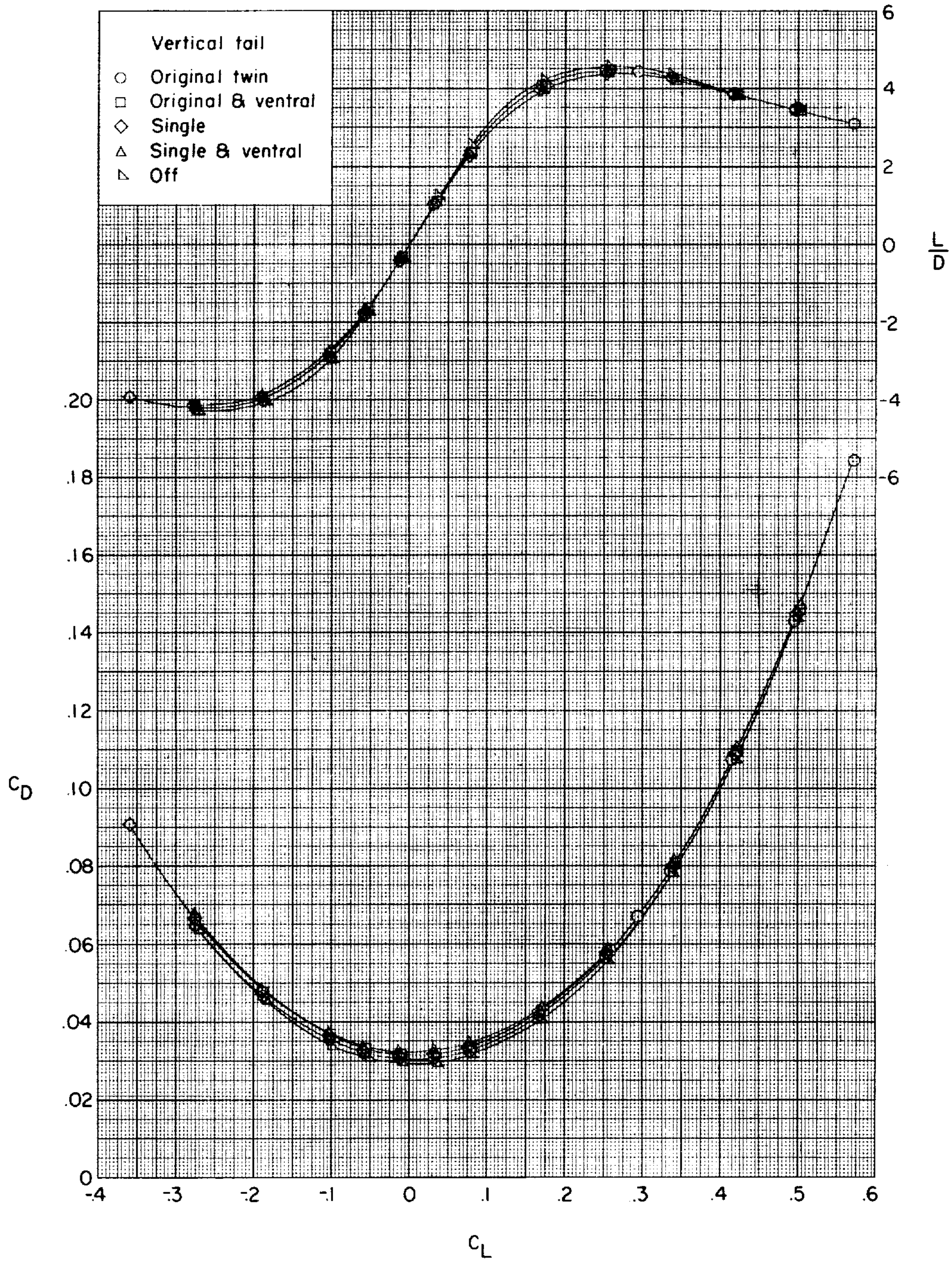

Vertical tail

Figure 2.- Details of ventral fin and single vertical tail.
All dimensions in inches unless otherwise noted.



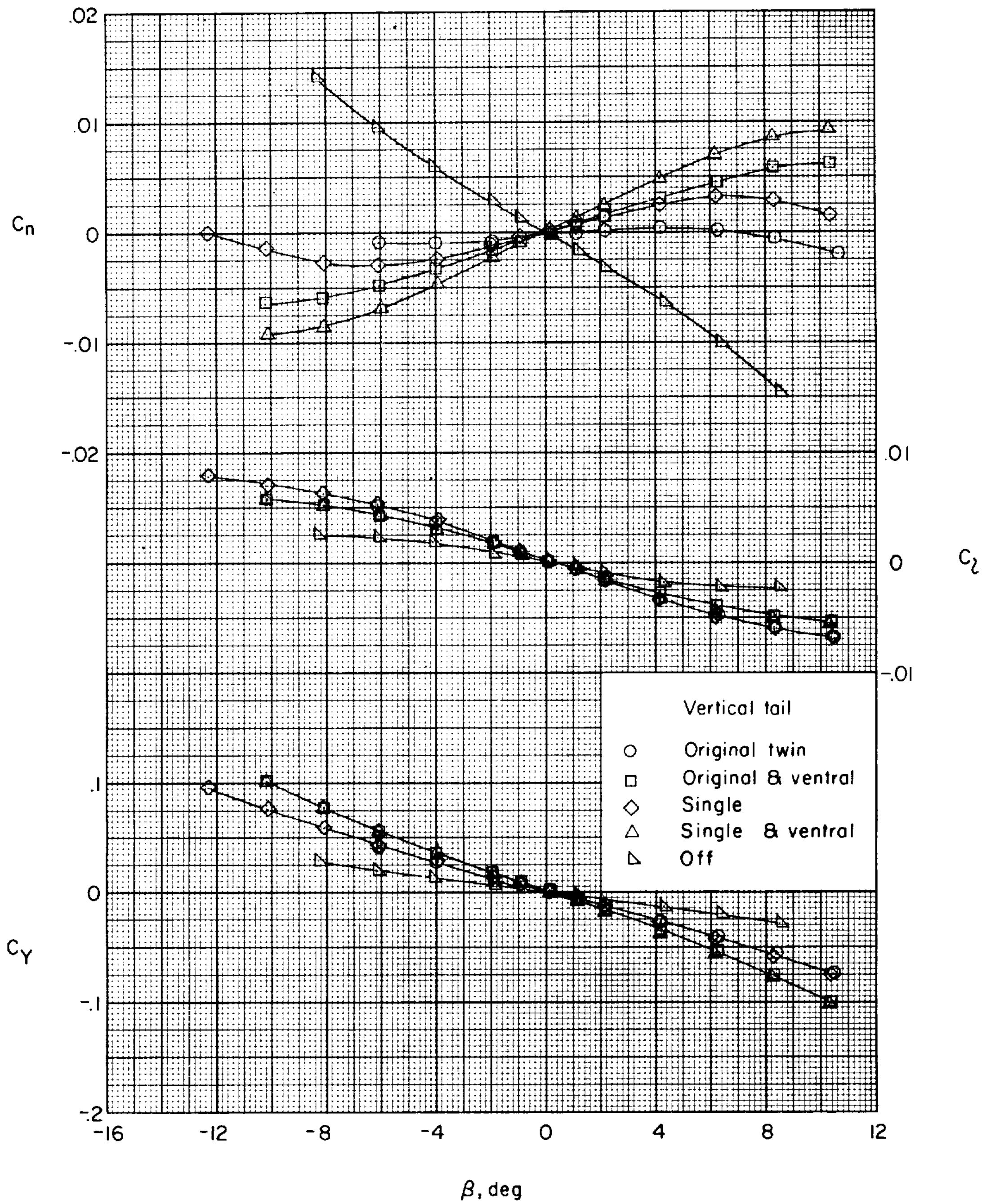

(a) Variation of $C_m$ and $\alpha$ with $C_L$.

Figure 3.- Effect of tail modifications on longitudinal aerodynamic characteristics.



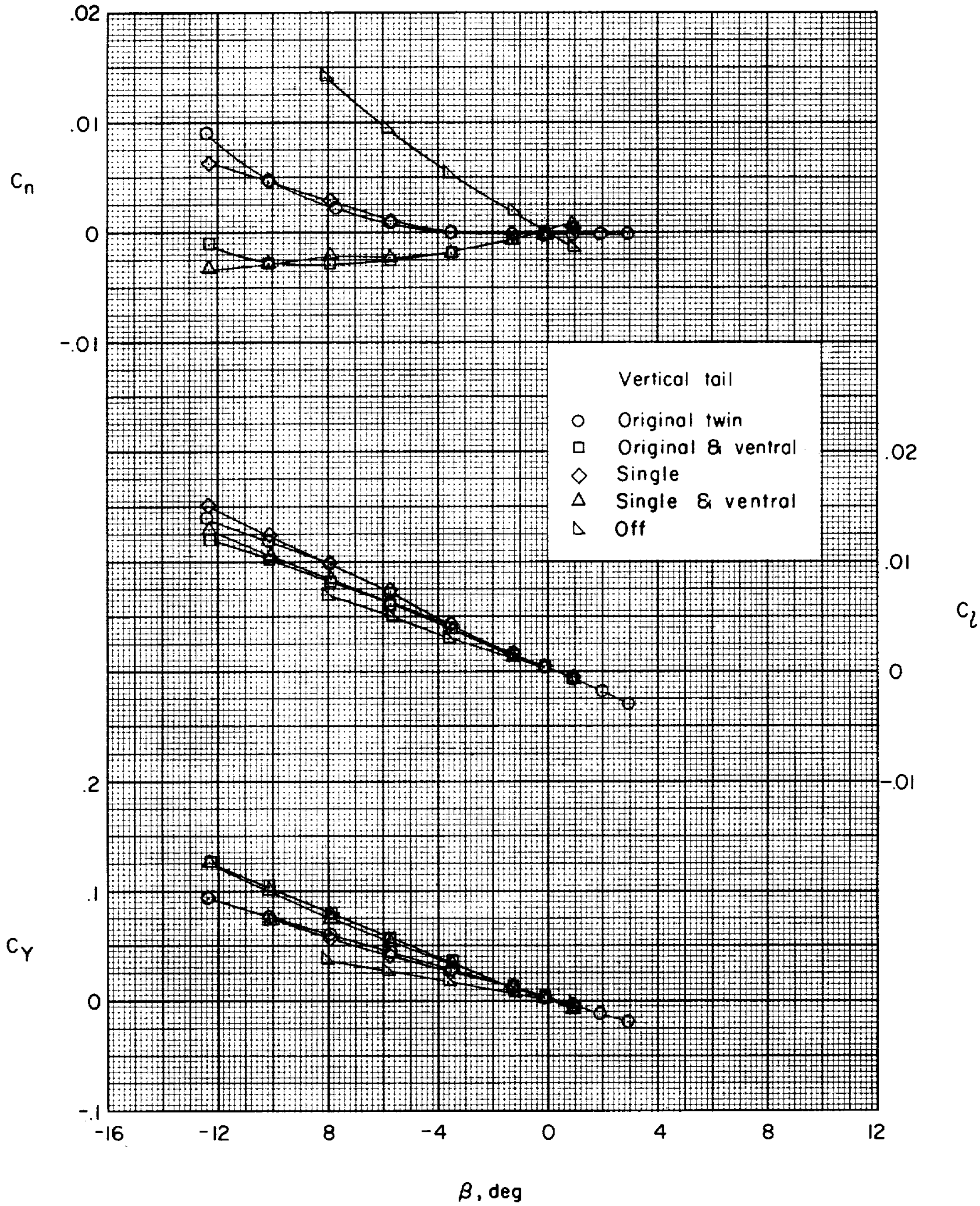

(b) Variation of L/D and $C_D$ with $C_L$.

Figure 3.- Concluded.



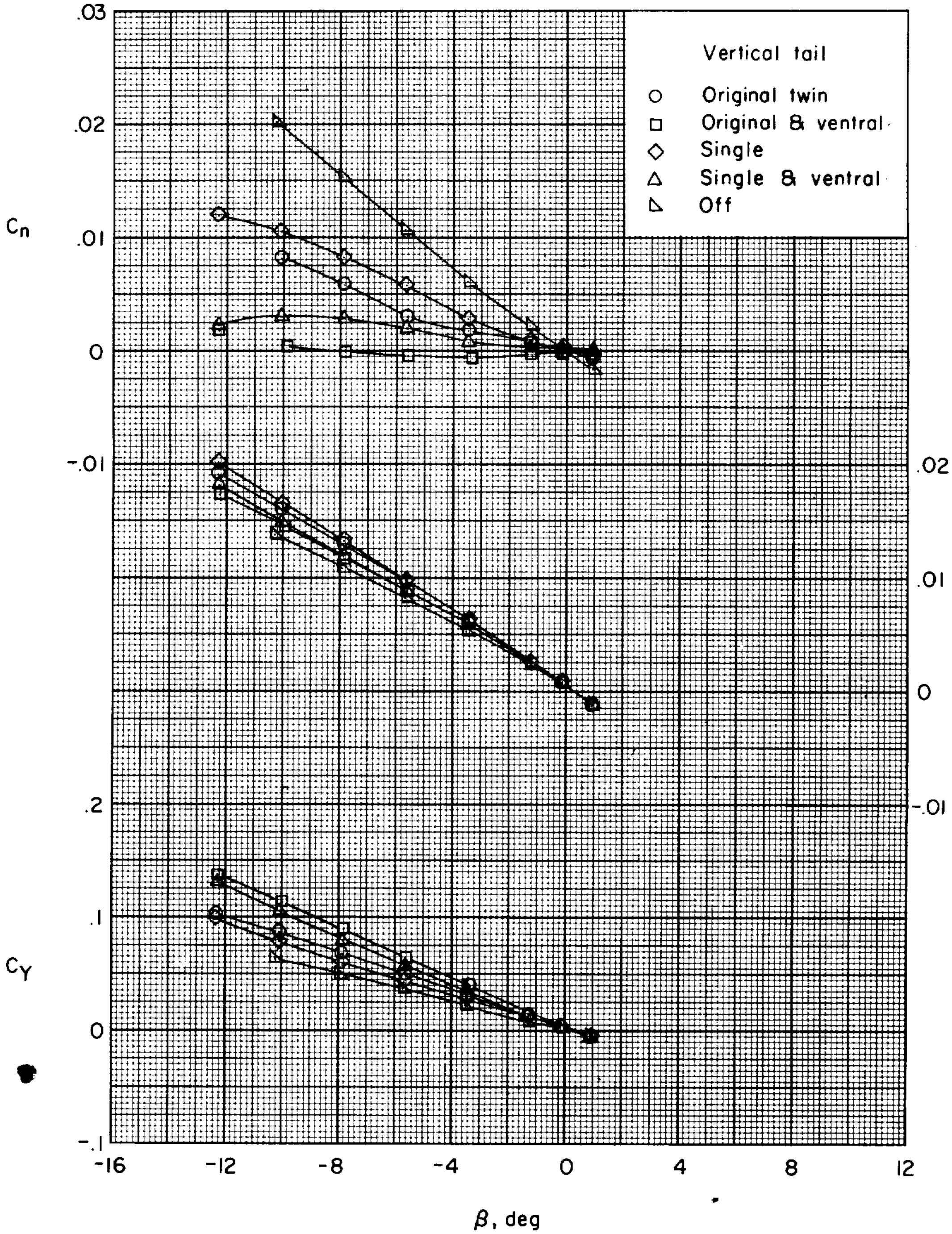

(a) $\alpha = -0.5^{\circ}$.

Figure 4.- Effect of tail modifications on the aerodynamic characteristics in sideslip for various angles of attack.



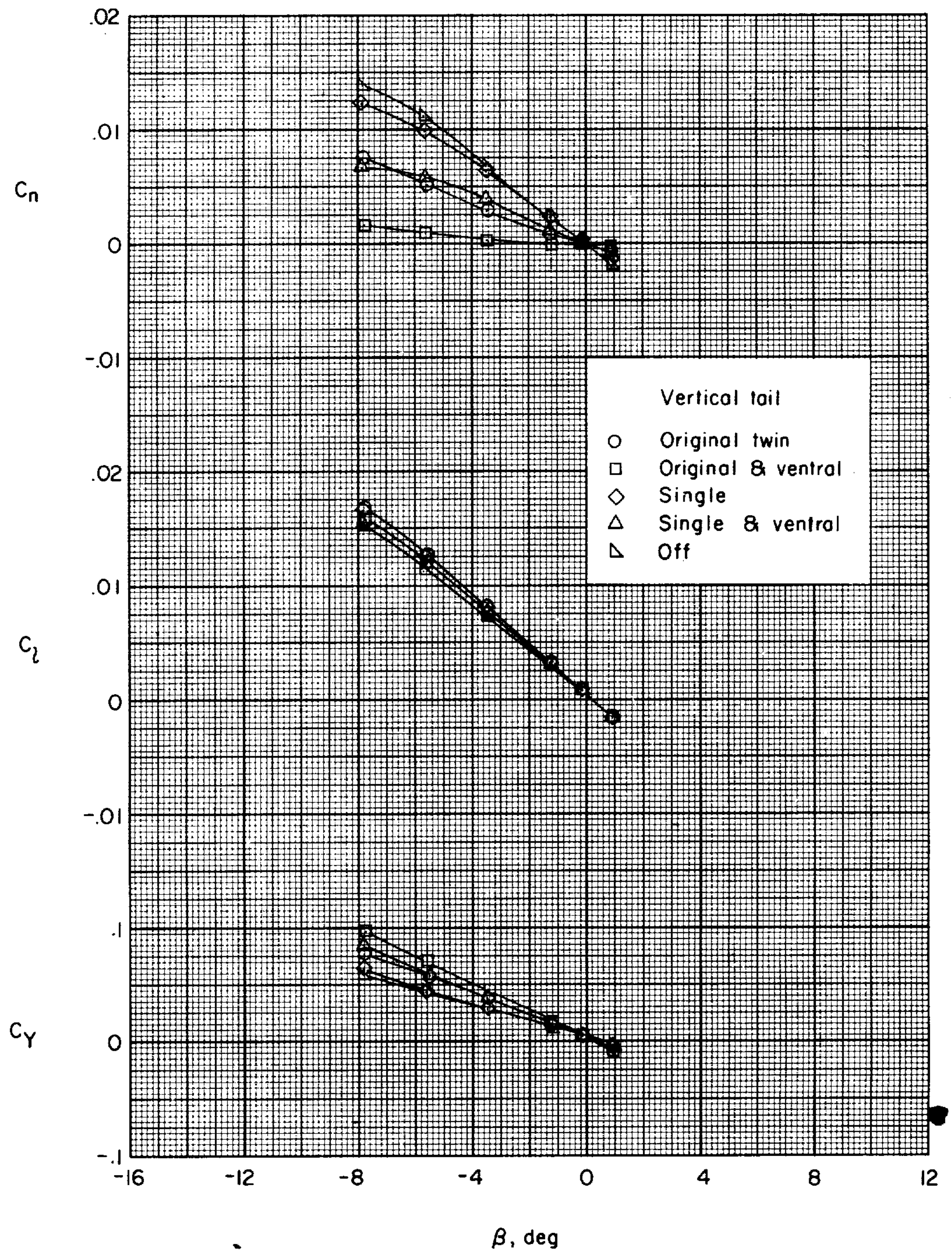

(b) $\alpha = 4.6^{\circ}$.

Figure 4.- Continued.




(c) $\alpha = 9.1^{\circ}$.

Figure 4.- Continued.




(d) $\alpha = 13.6^{\circ}$.

Figure 4.- Concluded.

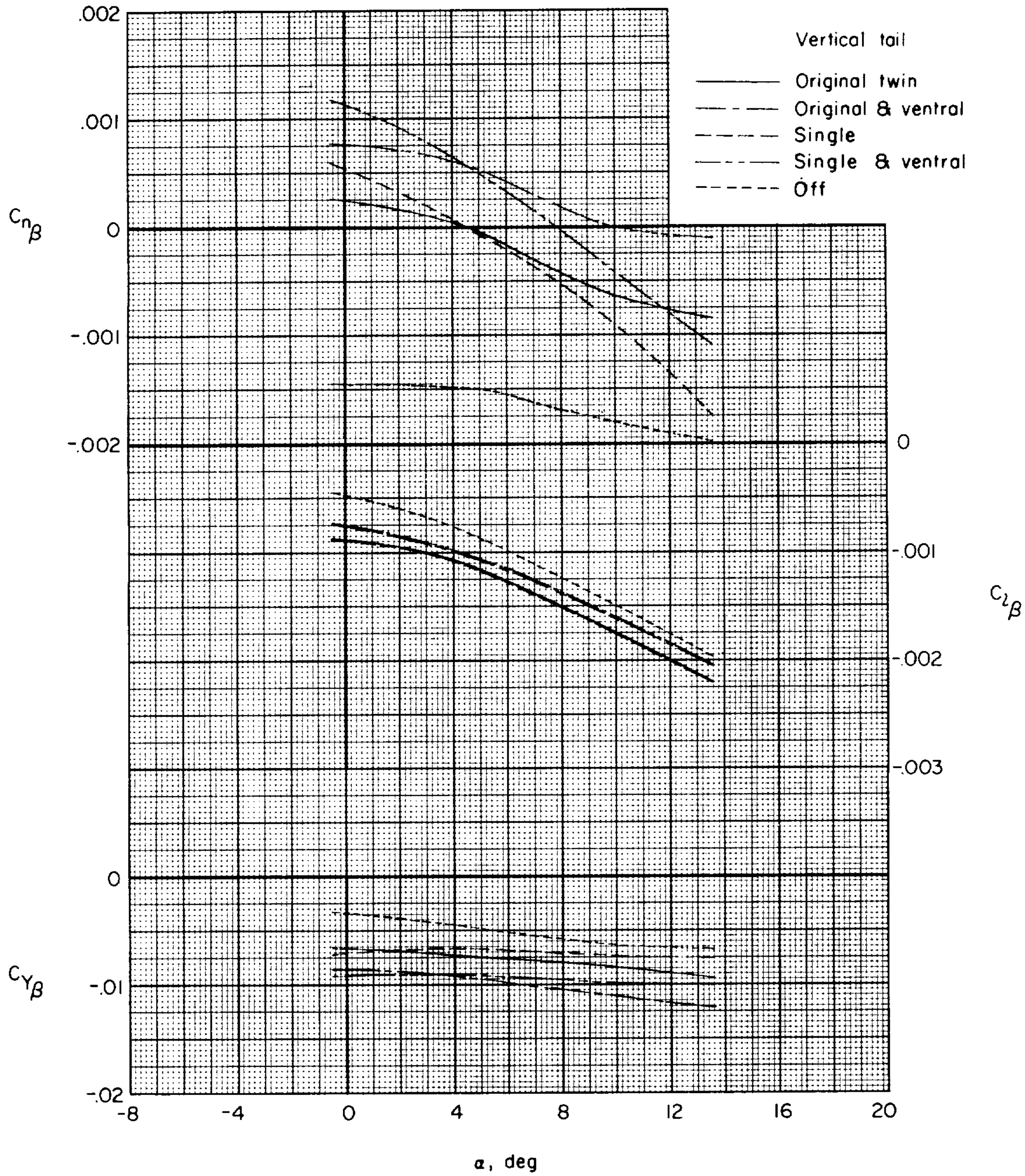



Figure 5.- Effect of tail modifications on the static sideslip derivatives.

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